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Vol. 26 — No. 9

CONTENTS

ORIGINAL PAPERS

A Sensitometric Method of Refraction—Theory and Practice. Matthew Luckiesh and S. K. Guth 367

Accommodation and Convergence with Contact Lenses. Mathew Alpern 379

Experimental Investigation of Vertical Fusion. Part II. Vincent J. Ellerbrock 388

The Use of Occlusion in the Treatment of Amblyopia. Five Case Reports. Marian K. Eakin and Robert S. Eakin 400

EDITORIALS

Essential Research Usually Undramatic. Carel C. Koch 405

SPECIAL REPORTS

American Optometric Foundation Announcement of Fellowships. William C. Ezell 408

CURRENT COMMENTS 409-412

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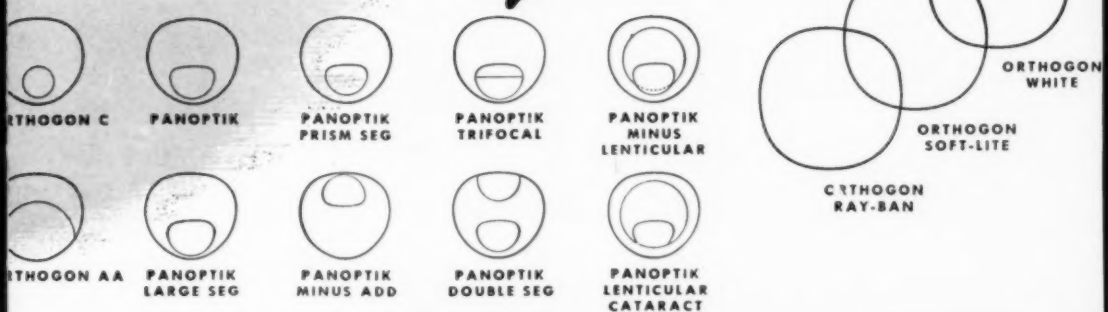

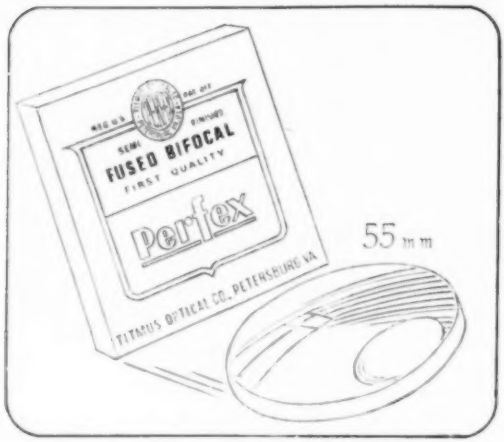

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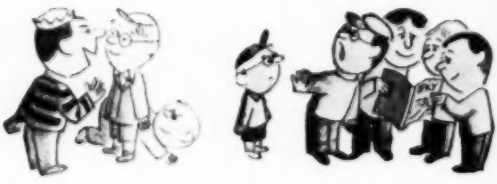

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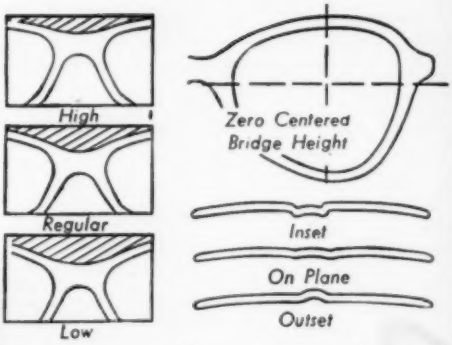

Length of Lens	DBL	Inclination	Temple Length
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38	14	On Plane	5¼"
38	16	Inset	5¼"
38	16	On Plane	5¼"
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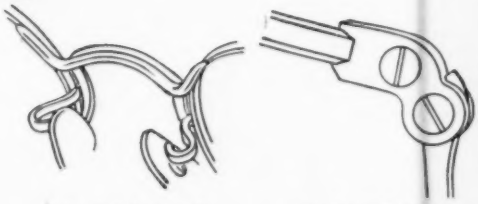

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38	18	20	22	24
40	18	20	22	24

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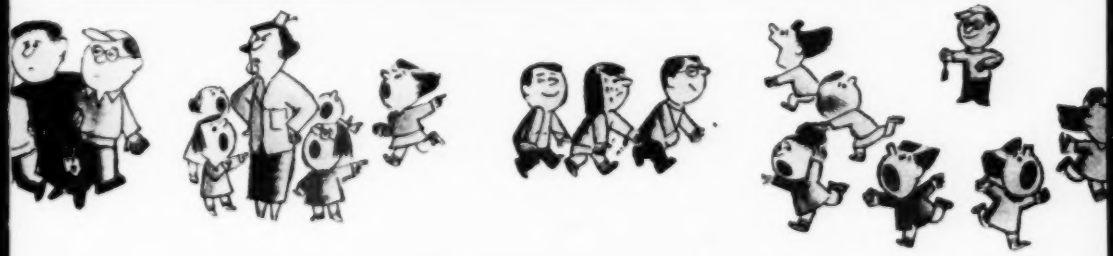

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Vol. 26 SEPTEMBER, 1949 No. 9

A SENSITOMETRIC METHOD OF REFRACTION—THEORY AND PRACTICE*

Matthew Luckiesh and S. K. Guth†
Lighting Research Laboratory
General Electric Company
Nela Park, Cleveland, Ohio

An important function of the examination of an ametropic eye is to produce sufficient information upon which can be based the specifications for the proper dioptric power to attain normal vision and comfortable seeing. Subjective methods have always been of major importance in the determination of the proper refraction including the interpretation of the objective measurements. However, while the basic criterion of visual acuity involved in the subjective technics is a convenient one, its use not infrequently necessitates some modification of the data in order to prescribe satisfactory corrections. Furthermore, the usual methods of measuring visual acuity make it difficult to determine precisely the correction which will yield maximal acuity. The arbitrary standards of so-called "normal" or 20/20 vision and the maximal amount of plus power which is acceptable without an appreciable loss in acuity introduce artifacts or ambiguities in the subjective procedures which often limit the precise evaluation of the degree of ametropia. It is a well-known fact that certain ocular anomalies do exist and often cause variations in the usual static and dynamic findings. Through clinical experience certain relationships have been established between the usual technics, and clinical procedure has developed certain expedients, allowances and biases to compensate for these anomalies. Nevertheless, it often is difficult and sometimes almost impossible, except by trial and error, to arrive at an adequate and proper diagnosis from the data.

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*Read before the annual meeting of the American Academy of Optometry, Winston-Salem, North Carolina, December 6, 1948. For publication in the September, 1949, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Fellows, American Academy of Optometry.

Any new technic, in order to be of value to the refractionist, should overcome at least some of the inadequacies and limitations now existing in the usual subjective examination. In other words, a new technic should fulfill several fundamental requisites. An important fundamental requirement is the absence of ambiguous standards, biases or allowances. That is to say, measurements of refractive errors should be in terms of a variable that is as nearly absolute as possible from a physiologic viewpoint. Secondly, it should provide a means of making measurements of the required dioptric power and of the effect of over or under corrections. A third requirement should be control of the functional factors involved. Unless this is accomplished there can be no guarantee that the true refractive condition of the eye has been determined. Therefore, a new technic should possess an inherently high degree of precision and reliability, by means of which it should be possible to obtain duplicate results on the same individual when used by different refractionists. In other words, such a technic should eliminate the possibility of introducing the human error provided certain simple instructions are followed.

SENSITOMETRIC PROCEDURES

The development of a new technic which appears to satisfy these basic requirements has resulted in the Luckiesh-Moss Ophthalmic Sensitometer. This instrument involves the use of a brightness-contrast threshold in place of the usual acuity threshold for the subjective determination of the dioptric power producing maximal visibility. An essential part of this technic is the target viewed by the patient which permits the functioning of convergence without presenting a stimulus for either positive or negative accommodation. Another important feature is that identical procedures are used under both dynamic and static conditions. Since the sensitometer and the basic theory have been described in detail elsewhere[1, 2], only a brief discussion is included here.

The Sensitometer. The instrument in its present form is illustrated in Figure 1. It consists essentially of two colorless circular photographic gradient filters which may be rotated synchronously before the eyes of the patient while he fixates a test-object. These gradient filters simultaneously alter the apparent brightness of the entire visual field by absorption and, of more importance, alter the brightness-contrast of all objects within the visual field because of the slightly diffusing character of the filters. Thus the test-object is reduced to the threshold of visibility by photometric changes. It is to be emphasized that the size and configuration of the test-object are constant factors in the measure-

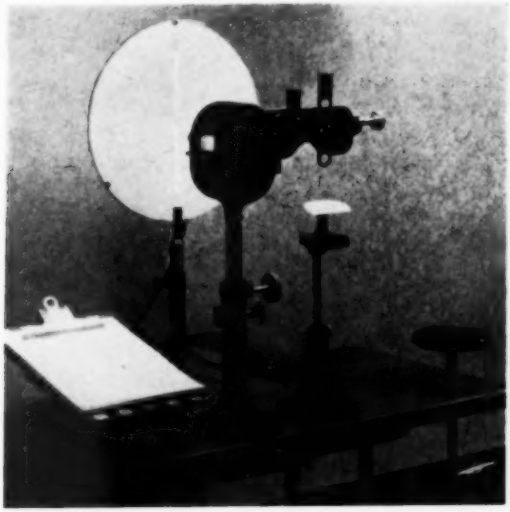

Fig. 1. The Luckiesh-Moss Ophthalmic Sensitometer in its present form.

ment of visibility. The knurled knob at the right controls the position of the gradients and the visibility values are read on the scale at the left. The method of calibrating this scale and its significance have been discussed elsewhere[3].

The Convergence Target. The specially designed fixation target consisting of a vaguely defined band of diffused light is located in the plane of the test-object and at right angles to the longitudinal axis of the latter as is illustrated in Figure 2. This relatively bright band of diffused light provides an adequate stimulus for binocular convergence and a minimal one for accommodation. The brightness of this luminous convergence target is adjusted so that it can be seen at all times, regardless of the density of the circular gradients.

The Test-Object. A special biconcave test-object is located at the center of an extended white field. The shape of this test-object is such that its visibility, under threshold conditions, is uniform throughout its longitudinal dimension. This characteristic adds to the precision of the sensitometric measurements. The brightness relations in the entire visual field are adjusted so that only the convergence target is seen through the gradients before the test-object has become visible. Since the test-object has a higher visibility than any other sharply defined object in the visual field, accommodation is inhibited throughout the

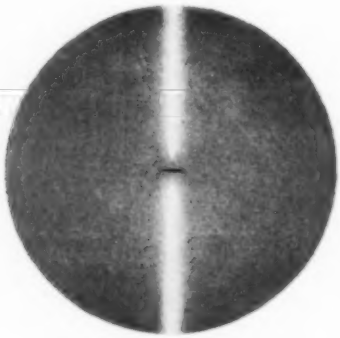

Fig. 2. The convergence target and the biconcave test object which are integral components of the sensitometric method.

period of measurement. In other words, the visibility of all other details of the visual field, excepting the vaguely defined convergence target, is reduced below the threshold by the filters and definite stimuli for accommodation thus are avoided.

Procedures. The sensitometer measures the relationship between the brightness-contrast threshold, expressed in terms of visibility, and the dioptric power placed before the eye. By determining the visibility of the test-object when viewed successively through each of a series of appropriate lenses, it is possible to determine graphically the dioptric power required to produce maximal visibility under either dynamic or static conditions.

The essential steps in this method are as follows:

1. A lens, usually a +2.50 diopter cylinder with its axis horizontal, is placed before the patient's eye that is not under examination. The purpose of this lens is to obliterate the image of the test-object without affecting the vertical convergence target and thus to confine the measurements to the other eye.

2. A series of cylindrical or spherical trial lenses, in half-diopter steps covering a range from about one diopter plus to one diopter minus from the power that is expected to yield maximal visibility, are placed successively before the eye that is under examination. Several measurements of visibility of the special test-object are made by the patient with each of these lenses.

3. The average visibilities obtained with each of the trial lenses are plotted as shown in Figure 3 for a vaguely defined convergence target, and straight lines drawn through these points. The resultant graph should be symmetrical about the axis of maximal visibility—an indication of the avoidance of accommodation. The apex indicates the dioptric power which will produce maximal visibility without the exercise of relative accommodation.

4. The correction producing maximal visibility may also be determined from three series of measurements indicated by points 1, 2 and 3 in Figure 3. Points 1 and 2 determine the linearity of the relationship between visibility and refraction. The bisector of a line connecting points of equal visibility on the "positive" and "negative" branches of the visibility-refraction relationship is indicated by M and represents the dioptric power yielding maximal visibility.

CHARACTERISTICS OF SENSITOMETRY

An extended series of exploratory investigations has indicated that the sensitometric method has certain fundamental characteristics which appear to make it a useful addition to the present refractive technics. These are presented in detail below.

Control of Convergence. The type of fixation target used (Figure 2) is an essential component of the sensitometric method[1]. The blurred vertical luminous elements provide binocular parafoveal stimuli of sufficient intensity to insure convergence at a point in the plane of the test-object. The lower diagram of Figure 3 illustrates the loss of sym-

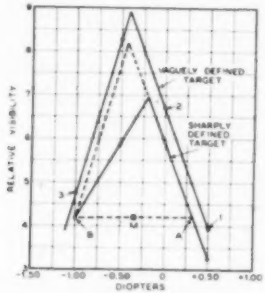

Fig. 3. Relationships between visibility and dioptric power for two types of convergence targets. The determination of the refraction by the "3-point" method also is illustrated.

metry thus indicating the exercise of accommodation. In this particular case, the accommodation was purposely stimulated by the use of a wide and sharply defined convergence target rather than the usual vaguely defined one. Both relationships of Figure 3 were obtained on the same subject. It is of interest to note that the use of the 3-point method of determining the refraction for maximal visibility from asymmetric data resulted in the same refraction as was indicated by the apex of symmetrical data. In the absence of an adequate stimulus for accommodation, convergence becomes the controlling factor in the sensitometric procedure, and the excess or deficiency of accommodation is the measured quantity.

Control of Accommodation. The avoidance of accommodation is an inherent characteristic of this method and is accomplished by the elimination of all adequate optical stimuli for accommodation from the entire binocular field[4]. The test-object is brought from a subthreshold condition to the threshold of visibility by gradually increasing its contrast and brightness, while the critical details of all other objects

remain invisible. Therefore, there is no physical stimulus for accommodation until the threshold of visibility, involving the mere recognition of the presence of the test-object, has been reached. The experimental confirmation of this is illustrated by Figure 4. It is evident that

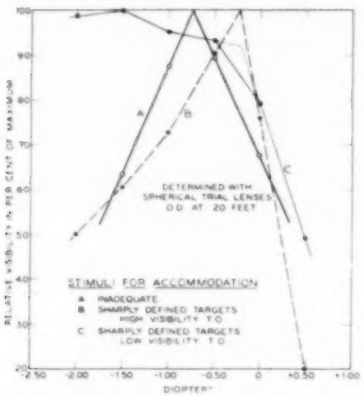
DETERMINED WITH SPHERICAL TRIAL LENSES O.D. AT 20 FEET
STIMULI FOR ACCOMMODATION
A INADEQUATE
B SHARPLY DEFINED TARGETS HIGH VISIBILITY T.O.
C SHARPLY DEFINED TARGETS LOW VISIBILITY T.O.
-2.50 -2.00 -1.50 -1.00 -0.50 0 +0.50 +1.00
DIOPTERS

Fig. 4. Illustrating the effects of three types of stimuli for accommodation upon the visibility-refraction relationships.†

decrements of visibility resulting from over and under additions of equal dioptric powers are equal when a vaguely defined convergence target is used as in A of the figure. Graphs B and C illustrate the degree of accommodation that is introduced when a sharply defined convergence target is used. A large, high-contrast test-object permits observations to be made through the relatively dense portions of the gradients. This density and the attendant diffusion reduce to a certain extent the definiteness of the convergence target and correspondingly reduce but do not eliminate the stimulus for accommodation. However, a low contrast test-object requires observations to be made through the lighter portions of the gradients, and thus the convergence target is highly visible and presents a strong stimulus. Obviously, if relative accommodation were stimulated by the trial lenses or by other factors, not even approximate symmetrical relationships between visibility and dioptric power would be obtained. Symmetry is taken as a critical indication of the control of accommodation with the sensitometric procedure.

Criteria of Emmetropia. The sensitometric correction of ametropia is that which produces maximal visibility without the exercise of accommodation. This is particularly significant because it is based upon a criterion that is absolute and fundamental insofar as any physical con-

stant can be so considered from a physiologic viewpoint. It is unnecessary to compare the maximal visibility obtained by any one subject with some so-called standard as is done when visual acuity is used as the criterion. Each subject is considered on an individual basis. Different visibility levels may be obtained by different observers for various reasons such as criterion of threshold, fatigue, retinal sensitivity, etc. Nevertheless, low values of maximal visibility do indicate that factors other than dioptric power, such as brightness of a visual task, are of great importance[5].

Identical Static and Dynamic Procedure. The refraction for near vision is measured directly by the sensitometric method by a procedure that is identical to that used for distant vision. The relationships between visibility and refraction for fixational distances of 20 feet and 30, 20 and 14 inches are shown for a typical subject in Figure 5.

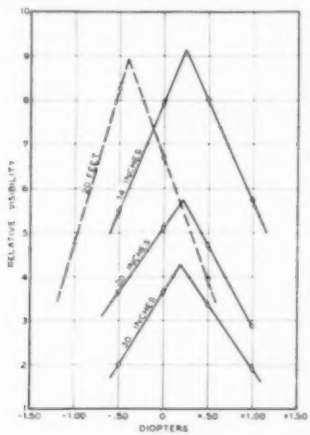

Fig. 5. Relationships between visibility and refraction for various fixational distances.

Since each of these graphs is symmetrical about the axis of maximal visibility, it is evident that accommodation was avoided at all distances. At present this method is the only one which yields dynamic information directly, as correction factors must be applied in other dynamic methods of refraction[6].

High Degree of Precision. The data obtained for a typical emmetropic subject during 10 successive near-point examinations are plotted in Figure 6 and are indicated by the solid circles. The refractions as obtained by the "3-point method" are represented by the open circles.

These data are typical of those obtained by the dynamic sensitometric method and indicate the precision of such measurements. Similarly reproducible results are obtained under static conditions.

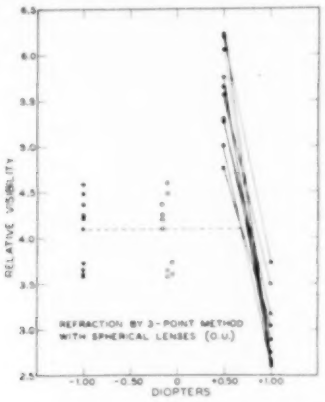

Fig. 6. Data obtained for a typical emmetropic subject at 10 successive near point examinations and represented by the "3-point" method of plotting.

CLINICAL PROCEDURE

A Luckiesh-Moss sensitometer has been in clinical use for several years during which period it has been used as a supplementary subjective test at the near point. Of 175 cases considered in this analysis and on which sensitometric findings have been taken, approximately half may be considered as so-called trouble cases in which refractive anomalies made the precise correction of the ametropia difficult.

The method of operating the instrument with various trial lenses as previously described was used. Both spherical and cylindrical trial lenses have been worn by the patients. In some cases it was found expedient for the operator to manipulate the sensitometer, and in others the patient adjusted the position of the gradients. Equally reliable data have been obtained by both methods.

During the course of obtaining these clinical data, various corrections were worn by the patients at the sensitometer. These included (a) present correction, (b) new astigmatic correction, (c) complete estimated new correction, and (d) no correction. The selection of the correction worn by the patient depended upon when the sensitometric findings were taken: that is, before or after the regular examination or whether it was a check test of a correction that had been previously prescribed. When bifocals were worn by the patient, observations were

made through the upper segment and additional plus power was used in the trial lenses to compensate for the required near correction. When an astigmatic correction was necessary, the correcting cylinders were worn and the spherical component was determined. The sensitometric results indicate the amount of dioptric power that must be added to the correction worn by the patient in order to obtain maximal visibility without the exercise of accommodation.

CLINICAL RESULTS

Since the usual methods of refraction are somewhat empirical in nature, it is obvious that the individual corrections prescribed by such procedures cannot be regarded as true bases from which to compare the results obtained by a different method. In fact, a so-called true base appears theoretically unobtainable since the usual ophthalmic correction represents an attempt to apply certain compromises based upon the viewpoint and experience of the refractionist. Nevertheless, it seems reasonable to assume that the "average corrections" and "average findings" of a representative group of individuals, which are obtained by various methods of refraction, are appropriate for revealing systematic differences between these methods. Such differences, if found, cannot be construed as errors inherent to one method or another since the examinations are conducted under different conditions, but it should be conceded that each method yields some information of a unique character.

The results of the refractions of the 175 cases have been summarized by grouping them in several manners in order to illustrate the relationships between sensitometry, the usual methods of refraction and the prescribed correction. Obviously, it would be impossible to present the complete clinical data for each case. However, these summaries should permit a general comparison of the results. While no data are presented regarding the duction and vision tests, they have been included by the refractionist in determining the final correction.

In order to simplify the presentation of the results, all findings have been reduced to single values representing the dioptric power in the vertical meridian. In other words, the spherical and cylindrical components have been combined and converted into the equivalent power of a single cylinder lens with its axis horizontal. The values indicated as having been determined by the sensitometric method include any correction worn by the patient plus the additional power that is required for maximal visibility.

The results of the 175 cases investigated are summarized in Table I. These averages substantiate the exploratory laboratory studies in

TABLE I

Comparison of sensitometric method with usual technics of refraction. Each datum represents the average of the findings obtained on 175 cases.

	Algebraic Mean Finding. Diopters		
	OD	OS	Average
Sensitometer	—0.16	—0.17	—0.17
Static Retinoscope	—0.72	—0.75	—0.73
Subjective	—0.73	—0.69	—0.71
Dynamic Retinoscope	+0.60	+0.66	+0.63
Cross-Cylinder	+0.25	+0.28	+0.26
Prescribed Correction	—0.24	—0.23	—0.23

that sensitometry consistently shows more plus or less minus power than the static retinoscope and the subjective technics. It will be noted that the final prescribed correction for the "average" eye is about the same as that indicated directly by the sensitometric examination. It is interesting to note that the relationships between the usual technics for the "average" case fall within the limits suggested by Haines[7] as being normal.

In Table II the data are grouped according to the dioptric power required for maximal visibility as determined by sensitometry. It is evident that there is close agreement between the prescribed corrections and the sensitometric findings for all groups. However, it is obvious that there is no direct and constant relationship between the usual technics and the prescribed correction. The differences between the usual technics of refraction and sensitometry are tabulated in Table III. No systematic variation of the differences between the prescribed correction and sensitometry is evidenced. However, the results of the usual technics show a definite trend as the dioptric range varied from high minus powers to high plus powers. The overall shift is about 1 diopter in the direction of a more minus or less plus differential. Since there is no corresponding trend in the satisfactory prescribed correction, this shift in all probability is caused by the inherent characteristics of the technics. In other words, a satisfactory correction may be prescribed from the usual static and dynamic tests provided the findings are modified by the clinical experience of the refractionist.

In order to further evaluate the results, Table IV has been prepared in which the clinical data have been grouped according to the type of correction given to the patients. These tabulations are in agreement with those previously discussed. The maximum difference between the averages of the prescribed corrections and the sensitometric data is about 0.12 diopter. For the group who received corrections for general use, the static tests are within 0.25 diopter of the prescribed

TABLE II

Summary of clinical results. The refractive findings are grouped according to the dioptric power required for maximal visibility as determined by sensitometry.

Sensitometry Range		Number of Eyes	Findings, Diopters: Sensitometry	Algebraic: Static Retinoscope	Mean Subjective	Dynamic Retinoscope	Cross-Cylinder	Prescribed Correction
—12.00	—8.12	9	—9.44	—10.30	—10.29	—8.30	—8.54	—9.18
— 8.00	—4.12	6	—5.29	— 5.04	— 5.42	—3.67	—3.71	—5.00
— 4.00	—3.12	10	—3.47	— 4.75	— 4.48	—3.00	—3.15	—3.78
— 3.00	—2.12	16	—2.56	— 3.30	— 3.08	—2.16	—2.21	—2.65
— 2.00	—1.62	10	—1.71	— 1.74	— 2.05	—0.72	—1.16	—1.80
— 1.50	—1.12	25	—1.31	— 1.85	— 1.89	—0.79	—0.83	—1.40
— 1.00	—0.62	20	—0.77	— 1.32	— 1.14	—0.09	—0.46	—0.79
— 0.50	—0.12	51	—0.31	— 0.59	— 0.53	+0.78	+0.20	—0.32
0		26	0	— 0.28	— 0.39	+0.92	+0.31	—0.08
+ 0.12	+0.50	85	+0.29	— 0.12	— 0.06	+1.20	+0.71	+0.18
+ 0.62	+1.00	28	+0.74	+ 0.26	+ 0.16	+1.67	+1.29	+0.43
+ 1.12	+1.50	9	+1.25	+ 0.92	+ 0.80	+2.08	+1.83	+1.26
+ 1.62	+2.00	14	+1.77	+ 0.65	+ 0.68	+2.10	+2.08	+1.86
+ 2.12	+3.00	24	+2.52	+ 1.47	+ 1.51	+3.07	+2.69	+2.39
+ 3.12	+4.00	10	+3.57	+ 1.74	+ 1.96	+3.44	+3.75	+3.65
+ 4.12	+8.00	7	+5.46	+ 3.66	+ 3.93	+5.75	+5.61	+5.57

correction. When it is necessary to prescribe separate corrections for near and distance, the cross-cylinder test is about 0.12 diopter more plus than the prescribed correction. For this group, the distance correction averaged —1.13 diopter which is in good agreement with the static tests and is what would be expected.

It appears from the data so far obtained that the refractive errors indicated directly by dynamic sensitometry are in the same direction as and are similar in magnitude to those indicated by the usual methods of

TABLE III

Differences between the usual technics and sensitometry.

Sensitometry Range		Number of Eyes	Sensitometry Mean	Differences, Diopters: Static Retinoscope	Subjective	Dynamic Retinoscope	Cross-Cylinder	Prescribed Correction
—12.00	—8.12	9	—9.44	—0.86	—0.85	+1.14	+0.90	+0.26
— 8.00	—4.12	6	—5.29	+0.25	—0.13	+1.62	+1.58	+0.29
— 4.00	—3.12	10	—3.47	—1.28	—1.01	+0.47	+0.32	—0.31
— 3.00	—2.12	16	—2.56	—0.74	—0.52	+0.40	+0.35	—0.09
— 2.00	—1.62	10	—1.71	—0.03	—0.34	+0.99	+0.55	—0.09
— 1.50	—1.12	25	—1.31	—0.54	—0.58	+0.52	+0.48	—0.09
— 1.00	—0.62	20	—0.77	—0.55	—0.37	+0.68	+0.31	—0.02
— 0.50	—0.12	51	—0.31	—0.28	—0.22	+1.09	+0.51	—0.01
0		26	0	—0.28	—0.39	+0.92	+0.31	—0.08
+ 0.12	+0.50	85	+0.29	—0.41	—0.35	+0.91	+0.42	—0.11
+ 0.62	+1.00	28	+0.74	+0.48	—0.58	+0.93	+0.55	+0.31
+ 1.12	+1.50	9	+1.25	—0.33	—0.45	+0.83	+0.58	+0.01
+ 1.62	+2.00	14	+1.77	—1.12	—1.09	+0.33	+0.31	+0.09
+ 2.12	+3.00	24	+2.52	—1.05	—1.01	+0.53	+0.17	—0.13
+ 3.12	+4.00	10	+3.57	—1.83	—1.61	—0.13	+0.18	+0.08
+ 4.12	+8.00	7	+5.46	—1.80	—1.53	+0.29	+0.15	+0.11
Weighted Mean		350	—0.17	—0.56	—0.54	+0.80	+0.40	—0.06

Table IV

Summary of clinical results. The refractive findings are grouped according to the type of prescribed correction.

	Sensitometer	Static Retinoscope	Subjective	Dynamic Retinoscope	Cross-Cylinder	Prescribed Correction
A. 33 Cases given separate corrections for near and distant vision.						
OD	+0.29	—1.19	—1.19	+0.66	+0.48	+0.39
OS	+0.06	—1.31	—1.23	+0.58	+0.42	+0.24
Average	+0.18	—1.25	—1.21	+0.62	+0.45	+0.31
B. 35 Cases given corrections primarily for near vision (normally not worn for distant vision).						
OD	+0.37	—0.12	—0.21	+1.32	+0.74	+0.25
OS	+0.38	—0.20	—0.14	+1.30	+0.76	+0.24
Average	+0.37	—0.16	—0.18	+1.31	+0.75	+0.25
C. 13 Cases given no correction for near or distant vision.						
OD	—0.05	—0.52	—0.40	+0.96	+0.42	0
OS	+0.07	—0.50	—0.23	+1.08	+0.58	0
Average	+0.01	—0.51	—0.32	+1.02	+0.50	0
D. 94 Cases given correction for general use.						
OD	—0.54	—0.80	—0.80	+0.26	—0.04	—0.67
OS	—0.48	—0.80	—0.77	+0.39	0	—0.60
Average	—0.51	—0.80	—0.78	+0.33	—0.02	—0.64

refraction after the adoption of various expedients in the latter procedures. Thus the sensitometric method adds to the science of refraction a subjective test, the characteristics of which would seem to make it especially useful when abnormal relations between accommodation and convergence are involved, as well as when precise corrections are demanded for near vision.

The authors are indebted to Dr. R. M. Hall, Cleveland, Ohio, for his invaluable assistance throughout the development of this sensitometric method and for obtaining the clinical data presented in this paper.

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ACCOMMODATION AND CONVERGENCE WITH CONTACT LENSES*

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INTRODUCTION

An error of refraction is always corrected by a lens placed at a finite distance anterior to the first principal plane of the eye. As a result, the amount that a given eye will accommodate to see a near object is a function of the optical properties of the eye, the ametropia, the location of the lens used to correct the ametropia as well as the location of the fixated object. It is the purpose of this paper to determine whether or not this fact is of clinical importance in the fitting of a contact lens inasmuch as the difference between the location of the contact lens which corrects the ametropia and the location of a spectacle lens which performs the same function for the same eyes is always appreciable.

It has been pointed out, recently, that a measurable difference between the astigmatism at distance and near may occur due to the location of the spectacle lens a finite distance anterior to the cornea.[1] Such a difference is based upon similar physical principles to these of concern in this paper.

When a lens is placed at a given distance (d) meters anterior to the primary principal plane of the eye, the vergence (V') of the rays of light from an object, emerging from the lens and measured with reference to the primary principal plane of the eye may be obtained by

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applying the fundamental abscissa relationship:

$$U' = U + F \tag{1.}$$

to the optical system. The result is:

$$V' = \frac{\frac{1}{v+d} + F}{1 - d\left(\frac{1}{v+d} + F\right)} \tag{2.}$$

In this equation v represents the distance in meters from the principal plane of the eye to the object and F the power of the lens in diopters. If the object is infinitely distant Eq. (2.) reduces to:

$$V'_{\infty} = \frac{F}{1 - dF} \tag{3.}$$

The amount of accommodation (Δ F) (Effective at the primary principal plane of the eye) which the eye must bring into play in order to see clearly a near object may be obtained by the following equation:

$$\Delta F = V'_{near} - V'_{\infty} \tag{4.}$$

which may be written as:

$$\Delta F = \frac{\frac{1}{v+d} + F}{1 - d\left(\frac{1}{v+d} + F\right)} - \frac{1 - dF}{F} \tag{5.}$$

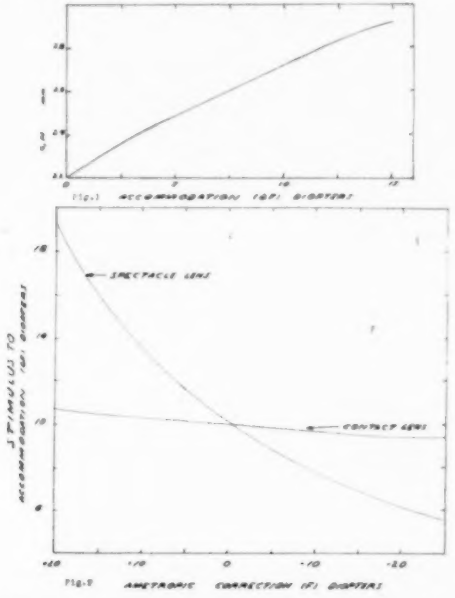
Eq. (5.) demonstrates the relationship which exists between the ametropic error, its location, and the amount of accommodation (with respect to the first principal plane of the eye) which must be brought into play to focus an object located at any given distance. For the sake of simplicity the lens which is used to correct the ametropic error has been assumed to be infinitely thin.

In the derivation of Eq. (5.) it was assumed that the principal planes of the eye remained stationary during the act of accommodation. Actually, of course, some shift of the principal plane does occur during accommodation, but it is extremely difficult to determine precisely how much, since too little data exist as to the changes in the radii, thickness, and position of the crystalline lens for unit changes of accommodation.

An idea as to the amount of the shift of the principal planes in the act of accommodation may be obtained by calculating the shift in the principal planes of Helmholtz' schematic eye with an afocal contact lens assuming that the thickness and the position of the crystalline lens remains constant and that the added dioptric power is distributed equally between the anterior and posterior surfaces of the crystalline

lens during the act of accommodation. Such computations are purely hypothetical since the available data indicate that the center of the lens not only becomes thicker, and moves forward during the act of accommodation but also that the anterior surface of the lens assumes most of the added power. Nevertheless these assumptions are the most convenient to make in order to illustrate the magnitude of the shift of the principal planes during the act of accommodation.

In Figure 1 the abscissa represents changes in accommodation in diopters and the ordinate represents the distance in millimeters of the



first principal plane of the accommodated eye from the anterior pole of the contact lens. It is seen from the figure that a change of accommodation of 15 diopters results in a shift of the principal planes of only 0.72 millimeters. Such a shift is so slight that it may be neglected and the assumption made in the derivation of Eq. (5.) may be considered permissible for the purposes of this study.

COMPARISON OF THE ACCOMMODATION WITH SPECTACLE AND CONTACT LENSES

The steep curve in Figure 2 is a graph of Eq. (5.) when applied to infinitely thin spectacle lenses placed 0.015 meters anterior to the

first principal planes of various axially ametropic eyes. The object distance v has been set at 0.1 meters. The abscissa in the figure represents various degrees of axial ametropia and the ordinate represents the amount of accommodation the eye must use in order to see the object clearly. The same qualitative effect could be demonstrated to exist for ametropia which is axial, refractive or mixed. However, recent evidence[2] seems to indicate that the most prevalent type of ametropia is axial. In axial ametropia the position of the principal planes of the eye will remain constant irrespective of the ametropia and the value of d in Eq. (5.) is thus kept constant. This simplifies the computation considerably.

From the curve it is seen that using spectacle lenses the axially myopic patient of 25 diopters will only accommodate 5.5 diopters to see an object 0.1 meters away, while the axially hyperopic patient must accommodate 19.2 diopters to see the same object at the same distance in space.

In plotting the curve for Eq. (5.) when contact lenses replace spectacle lenses it is satisfactory to assume that the refracting system, which includes the contact and the fluid lens (between the contact lens and the eye), may be treated as equal to an infinitely thin lens mounted 2.2 millimeters anterior to the primary principal plane of the eye.[3]

The second curve in Figure 2 is a plot of Eq. (5.) for a contact lens based upon the above premise with the stimulus to accommodation again taken as 10 diopters. The abscissa values for the ametropic correction have been converted back to the spectacle plane, for purposes of direct comparison of the two curves. This can be done by use of the following equation:

$$B = \frac{E}{1 + dE} \qquad (6.)$$

In this equation E is the power of the correcting lens in the plane of the contact lens and B is its power in the spectacle plane.

From this curve it is seen that for a fixed accommodation stimulus of 10 diopters, wearing contact lenses, a patient found to be 25 diopters myopic must accommodate 9.25 diopters while a patient found to be 20 diopters hyperopic must accommodate 10.7 diopters.

A comparison of the two curves of Figure 2 shows that a rather

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3. (a.) Obrig, T. E., Contact Lenses in Ametropia. Arch. Oph., 1937-1088 1120. (b.) Boeder, P. Power and Magnification Properties of Contact Lenses. Arch. Oph., 19, 1, 1938, 54-67.

striking difference exists between the amount of accommodation a given ametropic subject must use when wearing spectacle lenses as compared to that he must use when wearing contact lenses to see an object clearly at the same distance.

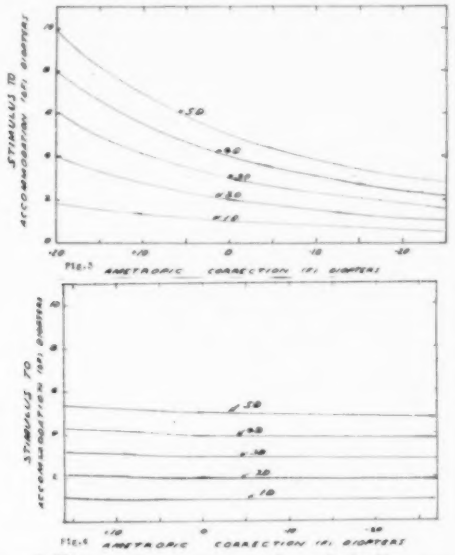


Figure 3 and Figure 4 represent series of similar curves to that of Figure 1 and were drawn to demonstrate the effect at stimulus levels of accommodation of 5D, 4D, 3D, 2D and 1D. The curves in Figure 3 are graphs of Eq. (5.) for spectacle lenses while the curves in Figure 4 are graphs of Eq. (5.) for contact lenses.

COMPARISON OF CONVERGENCE WITH SPECTACLE AND CONTACT LENSES

Since the accommodation that a patient will use to fixate a given distance when wearing spectacle lenses differs from that which he will use for fixating at the same distance when wearing contact lenses it follows that there must be a difference in the amount of accommodative convergence that the patient will bring into play in the two situations.[4] Hence in order to see a fixated object singly a different amount

4. (a.) Fry, G. A., An Experimental Analysis of the Accommodation-Convergence Relation. Am. J. Optom., 14, 11, 1937, 402-414; (b.) Fry, G. A., Further Experiments on the Accommodation-Convergence Relationship. Trans. Am. Acad. Optom., 12, 1938, 65-74; (c.) Hofstetter, H. W., The Zones of Clear Single Binocular Vision. Am. J. Optom. & Arch. Am. Acad. Optom., 22, 7-8, 1945.

of fusional convergence must be employed when contact lenses are worn than the amount used to fuse the same object when spectacle lenses are worn.

A reasonably accurate quantitative determination of this difference is obtainable. Let C_f represent the fusional convergence a given patient will use when spectacle lenses are worn and C'_f the fusional convergence the same patient will use to see an object at the same distance when contact lenses are worn.

Let: $$\Delta C_f = C'_f - C_f \qquad (7.)$$

The fusional convergence that a given bespectacled, isometropic patient will bring into play to see a near object singly is a function of the interpupillary distance in centimeters (P), the location of the fixated object, the ACA ratio (R), the location of the spectacle lens, the so-called proximal convergence (C_p), the tonic convergence (C_t), the dioptric power of the spectacle lens, and the distance in centimeters that the eyes look nasal to the center of the major reference point of the lens while fixating the near object (X). The relationship is:

$$C_f = \frac{P}{v+S} - R\Delta F - C_p - C_t - 2FX \qquad (8.)$$

In this equation ΔF is the accommodation in play as determined by Eq. (5.) and S is a constant representing the distance from the first principal plane to the center of rotation of the eye.

The second term in the right hand expression in Eq. (8.) represents the accommodative convergence and is determined by multiplying the ACA ratio by the amount of accommodation in play. The last term in Eq. (8.) represents the convergence caused by the prismatic effect induced by eccentric fixation in the spectacle lenses when the eyes fixate a near object.

The fusional convergence which the same patient will employ to see an object at the same distance when wearing contact lenses may be expressed in a similar manner as follows:

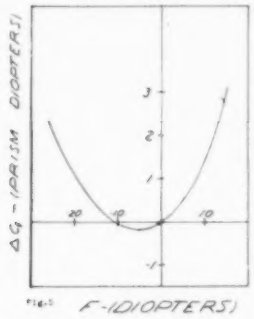
$$C'_f = \frac{P}{v+S} - R\Delta F' - C_p - C_t \qquad (9.)$$

Substituting Eq. (8.) and Eq. (9.) in Eq. (7.) gives:

$$\Delta C_f = R\ (\Delta F - \Delta F') - 2FX \qquad (10.)$$

Eq. (10.) is the relationship between the ametropic error and the difference between the amount of fusional convergence necessary to see an object singly with spectacle and contact lenses. Figure 5 is a graph of Eq. (10.). In plotting this curve the fixated object was taken at $\frac{1}{3}$ meter, the value of X was assumed to be 0.15 centimeters and the

ACA ratio assumed to be 4.5. The ordinate in the figure represents the value of ΔC_f in prism diopters, and the abscissa the ametropic correc-



tion in diopters. In the determination of this graph X has been assumed to remain fixed which is, of course, only an approximation of the actual situation.

It is seen from the figure that the difference between the fusional convergence used by a patient with contact lenses and spectacle lenses is not very great. This is in direct contrast to the effect on accommodation and seems somewhat paradoxical in view of the intimate relationship of accommodative convergence and accommodation.

The explanation lies in the fact that a compensatory mechanism exists in the prismatic effect induced by eccentric fixation in a spectacle lens while fixating a near object. This prismatic effect is of such a nature that it increases the fusional convergence required by a hyperope to fixate a near object and decreases the amount of fusional convergence required by a myope to see a near object. Due to the difference in accommodation the bespectacled hyperope would require less fusional convergence (than with contact lenses) and the bespectacled myope more fusional convergence. These two effects tend to cancel one another so that a negligible difference usually exists between the amount of fusional convergence that a given patient will employ to see a near object singly with spectacles and contact lenses. Some variation in this effect may occur, however, depending upon the value of R and X in Eq. (10.).

DISCUSSION

The fact that the eye will accommodate a different amount for fixating the same near object depending upon whether a spectacle or a contact lens is used to correct the ametropia is of extreme importance in

the clinical practice of contact lens fitting. This is especially true since contact lens patients are typically individuals with high or moderately high ametropia, i.e., in that range where the effect is most striking.

Since most patients cannot wear their contact lenses throughout the entire day it is usually necessary for them to alternate between spectacle and contact lenses. As a result different habits of accommodation must be learned for reading at the same distance depending upon whether the spectacle or the contact lenses are worn. This stresses the need for controlled research to determine the value of orthoptics in assisting patients to adapt to their contact lenses.

Another implication of this effect should be pointed out. Anisometropic patients frequently experience discomfort while reading through spectacle lenses. The most popular theory to explain such discomfort has been based upon the artificial vertical imbalance which is said to be created by the prismatic effect induced by eccentric fixation in the spectacle lenses while reading. Clinical results of treatment on the basis of this theory have not been completely successful.[5] An inspection of Figure 2 and Figure 3 reveals another factor which may contribute to the discomfort in such patients. It is seen that anisometropic patients must bring into play different amounts of accommodation in the two eyes for reading with spectacle lenses. Such unequal accommodation would usually be reduced to a negligible minimum with contact lenses.

The phenomenon described in this paper is also of clinical significance in the prognosis of the effect of contact lenses on presbyopic patients. It will be obvious from the curves of Figures 2, 3 and 4, that hyperopic patients should be able to postpone the necessity for a reading addition while wearing contact lenses. It should be possible for some hyperopes who require a reading addition when wearing spectacles to read quite well without any addition while wearing contact lenses. Clinical experience verifies this fact.[6] Myopic patients, on the other hand, may require a reading addition when wearing contact lenses where no such addition is necessary when ordinary spectacle lenses are used.

SUMMARY AND CONCLUSION

1. A clinically important difference may exist between the amount of accommodation that a given patient will use to see clearly

5. Ellerbrock, V. J., A Clinical Evaluation of the Compensation for Prismatic Imbalances. Am. J. Optom. & Arch. Am. Acad. Optom., Vol. 25, No. 7, 1948, 309-326.
6. Rowe, A. J., Contact Lenses and Presbyopia—A Case Report. Proceedings of The Staff of The Cleveland Contact Lens and Visual Center, 1947, submitted for publication in Am. J. Optom. & Arch. Am. Acad. Optom.

a near object when wearing contact lenses and the amount he will use to see the same object at the same distance when wearing spectacle lenses. The myope will have to use more accommodation to see at a given distance when wearing contact lenses than he does when wearing spectacle lenses. The hyperope will use less accommodation to see at a given distance when wearing contact lenses than he does when wearing spectacle lenses.

2. This difference has implications as to the value of orthoptics in assisting patients to adjust to contact lenses as well as to the fitting of prepresbyopic and presbyopic patients with contact lenses and to the optical therapeutics of anisometropic patients.

3. This difference in accommodation will result in a difference in the amount of fusional convergence that a patient will use to fixate a given near object with contact lenses and the amount he will use to fuse the same object at the same distance when wearing spectacle lenses. Such a difference in fusional convergence may not be of clinical significance, however, because it may be compensated for by the prismatic effect induced by eccentric fixation while looking at a near object through spectacle lenses.*

*The effects described in this paper are entirely dependent on the optical properties of spectacle and contact lenses. Such effects on accommodation and convergence which may occur as a result of the physical fit of the contact lens have not been considered. Since the presentation of this paper at the 1948 annual meeting of the American Academy of Optometry similar results have been described by Buerki (Das Haftglas als Optisches Instrument. S. Karger. Ltd., Basel and New York. pp. 211-217), in the comparison of accommodation with contact lenses with that through spectacle lenses. No effort was made by Buerki to compare the convergence values in the two situations.

ABSTRACTS

ROUTINE EXAMINATION ADAPTED TO THE NEEDS OF THE FACTORY OPTOMETRIST. D. W. A. Mitchell. The Optical Practitioner. (London). 2.7.152-158. 1948.

Mitchell suggests the following minimum refractive routine for industrial eye examinations and refractions. (1) symptoms and case history. (2) cover test. (3) ocular motility. (4) pupillary reactions and palpation for tension. (5) external ocular inspection under focal illumination. (6) ophthalmoscopy. (7) retinoscopy. (8) subjective refraction. (9) amplitude of accommodation. (10) phorias and ductions, and (12) stereoscopic tests. The author reviews the application of each test to the visual problems of factory workers.

C. C. K.

THE IMPORTANCE OF SMALL ERRORS OF REFRACTION. S. Black. Association of Optical Practitioners Newsletter. (London). No. 23. August 4. 1949.

The author presents quotations and comments on the importance of correcting small errors of refraction. The quotations are from Sir Stewart Duke-Elder's Practice of Refraction. 5th edition. The author's purpose is to set at rest the accusations that too many corrections were being prescribed by optometrists under the English program of compulsory health insurance.

V. H.

EXPERIMENTAL INVESTIGATION OF VERTICAL FUSION*

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PART II‡

BRIGHTNESS OF THE FUSIONAL STIMULI

With the experimental apparatus used in this investigation the brightness of the fusional stimuli can be modified by using neutral filters in contact with the targets. By combinations of two or more filters of 10 per cent transmission the brightness of a target could be made 1/10, 1/100, 1/1000 or 1/10,000 of its original brightness.

The effect on a fusional amplitude of reducing the brightness of one target while the brightness of the other was kept constant is shown in Figure 10. The elevation of the fixed target was 0° and size of both targets was 0.50°. The brightness of the targets without filters was 600 c/m². From the data described in Part I relating to the effect of area of target to size of pupil, one would not expect a decrease in brightness of one target to affect the size of the pupils.

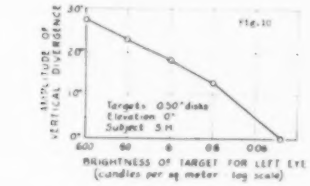
EFFECT OF UNEQUAL SIZES OF STIMULI

In order to investigate the effect of a relative difference in size on the inducement of fusional movements, targets of unequal size were employed. First, the amplitude of vertical divergence was determined with targets each of which was 2.00 degrees in size. Then the size of the target for the left eye was reduced 0.50 degrees and the experiment repeated. In the last experiment of the series the size of this target was only 0.50°.

The data given in Figures 11 and 12 are typical results, which show the marked effect of unequal image size on the inducement of fusional movements. The numbers adjacent to each curve are the sizes of the targets for the left eye; the size of the target for the right eye was kept constant at two degrees.

The disproportion between the magnitude of vertical divergence of the eyes and the separation of the targets is clearly illustrated in

*Read before the annual meeting of the American Academy of Optometry, Winston-Salem, North Carolina, December 5, 1948. For publication in the September, 1949, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrist. Member of faculty. Fellow, American Academy of Optometry.
‡Part one of this report appeared in the August issue.



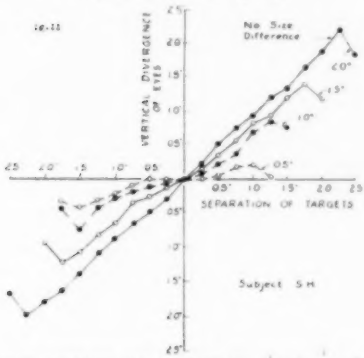


Fig. 10. (Top) Results showing the diminution of the amplitude of vertical divergence produced by a reduction in the brightness of a fusional target. The brightness of the target for the right eye was 600 c/m^2.

Fig. 11. (Bottom) Results illustrating the vertical divergence of the eyes induced by retinal images of unequal size.

Figure 12. It should be noted that the vertical divergence of the eyes was not altered by the separation of the targets until the separation was equal to one-half the difference in size of the fusional stimuli. These

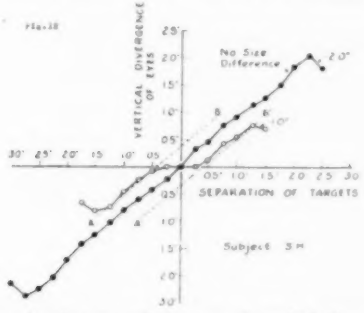


Fig. 12. The disproportion between the extent of vertical divergence of the eyes and targets is illustrated. The difference between the two parallel lines AB and A′B′ is approximately equal to the difference in size of the targets. The numbers adjacent to the curves are the sizes of the targets for the left eye. The size of the target for the right eye was 2 degrees in all the experiments.

results indicate the importance of the border in the inducement of fusional movements.

Of special interest is the comparison of the amplitudes of fusion which were secured when the size of both of the targets was 0.50° and when one was 0.50° and the second 2.00°. In the former case the amplitude of fusion was 3.60° and in the latter 0.55°. Such differences in the sizes of the amplitudes are not found for fusional stimuli which are relatively small in size. Typical results for small fusional targets are given in Table 2.

	Amplitude of Vertical Divergence	
Subject	Size of both targets 0.12°	Size of target for right eye. 0.12° left eye. 0.06°
S. H.	2.34°	2.23°
V. E.	2.51°	2.03°

Table 2. The effect of a difference in the size of fusional stimuli on the amplitude of vertical divergence is proven by these results. It should be noted that the targets were relatively small in size.

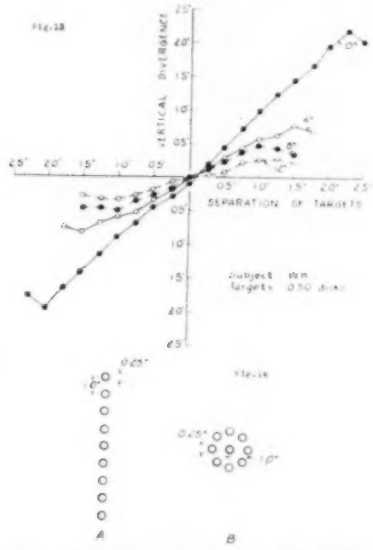


Fig. 13. (Top) The vertical divergence of the eyes induced by peripheral fusional stimuli is pictured above. On each curve is indicated the elevation of the fixed target above the fixation point.
Fig. 14. (Bottom) Two different types of targets used to investigate the role of the peripheral fusional stimuli in the inducement of fusional movements.

ROLE OF PERIPHERAL FUSIONAL STIMULI

It is known that similar stimuli located in the periphery of the retina can induce fusional movements. The amplitude of such movements, however, is less than when the same stimuli are in or near the fovea. The explanation for this change appears to be the relatively sparse distribution of ganglion cells to receptors in the periphery compared to the fovea. If this explanation is correct, there should be a disproportion between the vertical divergence of the eyes and the separation of the targets inducing the movements.

In order to investigate the fusional movements induced by peripheral retinal stimuli, identical targets 0.50 degrees in diameter were located at various elevations above the point of fixation. In each experiment the subject maintained fixation on a target which was at 0° elevation. When the fixed vertical fusion target was elevated 4 or more degrees, the cyclofusion targets were set at 0° elevation and used for fixation. For elevations of the fixed vertical fusion target less than 4 degrees, a disk 0.03° in size and seen only by the right eye was used for fixation. Representative results are given in Figure 13. The numbers on the curves are the elevations of the fixed target above the fixation point in degrees.

Table 3 gives the amplitudes of vertical divergence for different peripheral elevations of the target whose position was fixed during an experiment. The similarity of the results for the two subjects is noteworthy.

Elevation of Target	Amplitude of Vertical Divergence	
	Subject V. E.	Subject W. K.
0°	3.62°	3.99°
2°	1.32°	
4°	1.19°	1.45°
6°	1.04°, 1.00°, 1.08°	
8°	0.40°	1.15°
12°	0.36°	0.75°

Table 3. Results which show the amplitudes of vertical divergence produced by fusional stimuli located at different elevations in the visual field. The elevation of the target whose position was fixed during an experiment is given in the first column.

For many practical reasons, it is necessary to know the extent to which the fusional stimuli located in the periphery aid those in the fovea in the inducement of a fusional movement. This relationship was studied by the use of two different types of targets. One type consisted of a varying number of vertically aligned disks (Figure 14A); the other was made up of a varying number of disks located concentrically

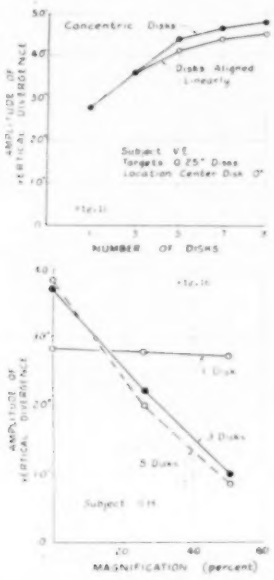


Fig. 15. (Top) Results illustrating the increase in the amplitude of vertical divergence which occurs with an increase in the number of peripheral fusional stimuli in the targets. The peripheral stimuli consisted of disks arranged in two different ways (cf. Fig. 14).

Fig. 16. (Bottom) Results showing the effect of a relative magnification of the retinal image for the right eye on the amplitude of vertical divergence. The number of disks in each pair of targets employed for the above data is indicated on the curves. Each disk was 0.25° in size and the separation of any two disks was 1.0°.

about a center disk (Figure 14B). The size of each disk was 0.25°. In the target having vertically aligned disks, the separation of any two disks was 1.0°. For the target having disks arranged concentrically all the disks were spaced 1 degree from the center disk.

Figure 15 graphically illustrates the change in size of the amplitude of vertical divergence which occurred with an increase in the number of disks in the targets. In each experiment one disk was located at 0° elevation. For the experiment with three disks, two additional disks—one above and the other below the one located at 0° elevation—were employed. Obviously, the difference in results with the two different types of targets is explained on the basis of the different peripheral locations of the disks.

Although the amplitudes of vertical divergence are increased by

the addition of peripheral fusional stimuli, the rate of increase is relatively small. This indicates that the images located in the foveas principally determine the positions of the eyes. In order to further elucidate this point, a number of experiments were made in which a pair of targets located at 0° elevation was kept at a fixed position while the vertical separation of a second pair of targets located at various elevations was altered. Conceivably, if the targets at 0° elevation are small in size—for example, 0.03 degrees—and the peripheral targets are 2 degrees in size, the position of the eyes might be determined by the fusional movements induced by vertical separation of the peripheral stimuli. If the foveal and peripheral targets are now interchanged, it follows that the position of vertical divergence of the eyes would be controlled by the foveal stimuli. Of course, it is expected that the elevation of the peripheral target whose position is fixed during an experiment would affect the results.

In the investigation which was made to determine the role of disparate peripheral fusional stimuli in the presence of non-disparate foveal stimuli, four different sizes of paired targets were used, namely, 0.03°, 0.12°, 0.50°, and 2.00°. Likewise, four different elevations of the peripheral targets were employed: these were 2°, 4°, 6°, and 8°. In every possible combination of these targets at the different elevations, the stimuli located in the fovea determined the position of the eyes. This means that dissociation of the images located in the fovea did not occur, even when the disparate peripheral targets were 2° in size, and located only 2° from the fovea.

MAGNIFICATION OF ONE RETINAL IMAGE

Clinically, it has been found that binocular vision is not possible if the image size differences for the two eyes are greater than 5 per cent. This immediately raises the question as to whether or not an individual would lose binocular vision if a 5 per cent size lens were worn before one eye. The following investigation bears a definite relation to this problem. The aim was to study how an overall increase in the size of a multipoint pattern for one eye will affect the vertical fusion amplitude.

In one series of experiments the targets for the two eyes consisted of one, three and five disks which were 0.25° in size. The separation between any two of the disks was 1 degree. When more than one disk was used, they were linearly arranged in the vertical direction.

The amplitudes of vertical divergence were determined for each of the three types of targets. In each experiment, the center disk of the target was fixated; its elevation was 0°. The size of the targets

for the right eye was then made larger in steps of 25 per cent and the fusional amplitudes determined.[4]

Representative results of the effect of the different types and sizes of targets on the fusional amplitudes are given in Figure 16. These definitely show the importance of the peripheral stimuli with a difference in angular magnification of the retinal images. It is significant that the results with the targets having 3 and 5 disks are practically the same. This suggests that the number of peripheral stimuli is not as important

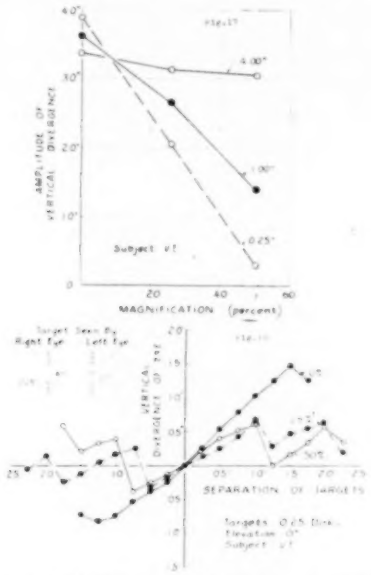


Fig. 17. (Top) Results which illustrate the influence of a magnification of the retinal image for the right eye on the amplitude of vertical divergence. The targets consisted of 3 disks which were 0.25° in size. The separations of the disks were 0.25°, 1.00°, and 4.00°.

Fig. 18. (Bottom). Illustration of the extent of vertical divergence of the eyes induced by various separations of the targets. The targets seen by the right and left eyes are shown in the small inset.

as the location of the stimuli with respect to the fovea. To further investigate this factor, the effects on the fusional amplitudes of the separations of three disks in the targets were determined. As in the previous

4. Not only were the size of the disks increased by this procedure but also the separations between the disks. In order to produce the same effect on the size of the retinal image by optical means as was accomplished by increasing the actual size of the target, an overall magnification lens system would have to be used.

series of experiments, the amplitudes were measured when the targets were equal in size, and also when the target for the right eye was increased 25 and 50 per cent in size. Graphical illustration of typical results is presented in Figure 17. The numbers adjacent to each curve are the separations of the disks in the target for the left eye. It is seen that the effect of a difference in the relative magnifications of the retinal images principally depends upon the location of the peripheral stimuli. This effect varies inversely with the distance of the stimuli from the fovea.

EFFECT OF SUPPRESSION

In light of the experimental data which have been presented it is apparent that a regional suppression of either the periphery or foveal region of a retina would have an effect on the functioning of the fusion reflex.[5] The most marked effect, of course, would result from a foveal suppression. Since the fusional amplitudes vary with a relative difference in magnification of the ocular images, it would be of interest to know the extent to which fusional movements are induced under conditions approximating both a foveal suppression and differences in sizes of the ocular images.

The targets employed to study this effect are illustrated by the small insets in Figure 18. The elevation of the center disk in the target for the left eye was 0°. The numbers on the curves indicate the relative magnifications of the target for the right eye. These results are important from two different points of view. One, they show that a significant amplitude of vertical divergence can be induced by peripheral fusional stimuli. This finding indicates that it is possible to have suppression with a limited amount of binocular vision. Secondly, the results prove that the presence of a relative difference in magnification of the ocular images impedes the function of the fusion reflex.

DISTORTION OF THE IMAGES

Frequently the situation is encountered when the images of three points will appear nonuniformly spaced for one eye and uniformly spaced for the other eye as shown in Figure 19. The nonuniform spacing seen by the one eye is a form of distortion. An investigation of the effect of a monocular distortion on the inducement of fusion

5. That a suppression does impair the inducement of fusional movements was demonstrated by Burian. He found "that patients in whom only peripheral fusional stimuli were effective showed as a rule a sensorial disturbance (suppression or change in the mode of localization or in the angle of squint) when the two foveas were stimulated simultaneously: patients who did not follow peripheral fusional stimuli usually did not show a sensorial disturbance of the central parts of the retinas but suppressed the images of one retinal periphery" (Burian, H. M.: Arch. Ophth., 26: 650, 1941).

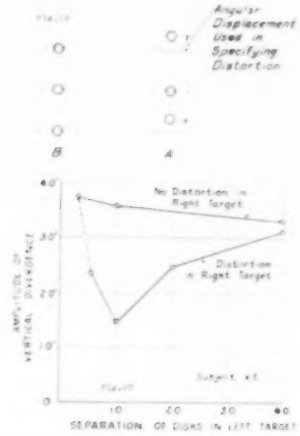


Fig. 19. (Top) The distorted image seen by the right eye is indicated by A. The image seen by the left eye is designated by B.
Fig. 20. (Bottom) Data showing the extent of vertical fusional movements induced by targets in which the disks were separated different amounts. The distortion in the right target was 0.25°.

movements was carried out by using a target consisting of a row of vertically aligned disks which were uniformly spaced for the left eye and nonuniformly spaced for the right eye. The interval between the top and center disks was increased by the same amount as the interval between the center and bottom disks was decreased. The ratio of this interval to the separations of the disks in the target for the left eye was used as a measure of distortion.

The size of all the disks in the targets was kept constant at 0.25°. This was done even though it was known that a distortion would cause differential magnifications of the disks. In fact, a distortion would produce elliptical images of circular targets. Since the size of each disk was only 0.25°, these changes in size were considered negligible on the basis of the findings presented in the second section of Part II, and especially in Table 2. The separation of the disks in the target for the left eye was 1.0°, and this separation was kept constant throughout the series of experiments. Fixation was maintained on the center disk in the left target which was at 0° elevation. The experimental results of the effect of distortion on the amplitude of vertical divergence are given in Table 4. While the gradual diminution of the fusional amplitude with increasing distortion is obvious, the explanation of the change needs clarification. In Figure 19 are shown the relative posi-

tions of the three disks in the fusion target for the right eye. The two peripheral disks are deviated in the direction indicated. As a result, the positive vertical divergence is markedly impaired while the negative component is unaltered. If the peripheral disks had been displaced in the opposite direction, the effects would have been reversed.

The effect of using different separations of the uniformly spaced disks in the left target and keeping a constant amount of distortion in the right target is illustrated in Figure 20. The targets consisted of three disks which were 0.25° in size and the distortion in the right target was 0.25°. The finding of special importance is that the disparate images located close to the fovea markedly impaired the inducement of fusional movements by the foveal images.

Distortion	Amplitude of Vertical Divergence
0.05	3.07°
0.10	2.80°
0.175	2.20°
0.25	1.47°
0.375	1.45°
0.50	1.79°

Table 4. Illustrating the effect of different amounts of distortion on the amplitude of vertical divergence. The targets consisted of 3 disks which were 0.25° in size.

SUMMARY OF RESULTS AND CONCLUSIONS

The experiments in this investigation have demonstrated that the essential, adequate stimulus for a vertical fusional movement is a vertical disparity in the placement of horizontal parallel borders on the two retinas.

This was shown first of all in the experiments with disk-shaped stimuli of unequal size. The results indicate that the fusion reflex operated in the direction of keeping the two disks tangent to each other at some point. The point of tangency is on the same side and in the same direction as the displacement of the smaller disk from the center of the larger disk.

Additional evidence of the importance of the border are the findings from the experiments in which the borders of one or both fusional stimuli were blurred. When both borders are equally blurred the amplitudes of fusion induced by separating the fusional stimuli were not appreciably different from the amplitudes secured with stimuli whose borders were not blurred. When only one fusional stimulus is blurred, the amplitude of the fusional movement is reduced. The reduction in brightness at the center of the retinal image which occurred with the higher degrees of blurredness of the fusional stimulus is not the essential change in the stimulus to which the impairment can be ascribed. This

follows from the results of the experiments in which the brightness of one fusional stimulus was reduced. These results demonstrate that a diminution of the amplitude of fusion only occurs with much greater decreases in the brightness of a stimulus than that which could be attributed to the blurring.

It was shown that fusional movements cannot be equally induced by images located at different portions of the retinas. An explanation of the cause of this inequality needs to include a consideration of the distribution of the ganglion cells. In the peripheries of the retinas the ganglion cells are less concentrated than the rods and cones and consequently a number of rods and cones converge upon a single ganglion cell. The ratio of cones to ganglion cells for the fovea is generally assumed to be one to one.

Most investigators favor the view that fusional movements are only induced when the attention is directed to a visual object. However, these investigators have not clearly differentiated between two possible roles that attention might play in this phenomenon. On the one hand, if the fusional stimuli fall outside the fovea, paying attention to the object producing the images will cause the eyes to move so that the images are brought toward the foveas. Thus a fusional movement might become possible by virtue of the fact that the reflex is stronger when stimuli fall on the foveas. On the other hand, if the images are originally close to the fovea one must consider whether concentration on one or the other of the members of the doubled image will induce a fusional movement.

The fact that attention to the fusion stimuli is not a necessary condition for fusion is shown in the experiments involving a monocular fixation target for the fovea and fusional targets in the periphery. In this case, fusional movements were induced although the subjects did not direct their attention to the fusional stimuli. As a consequence, they did not know whether the stimuli were fused or the extent of the movements.

The summative effect of fusional stimuli in the periphery and the fovea on the inducement of fusional movements was clearly demonstrated. This effect was shown to vary with the number of peripheral stimuli and their location on the retinas. Likewise, the data indicate that the effect gradually increases and reaches a maximum, beyond which the addition of more peripheral fusional stimuli will not significantly increase the amplitudes of fusion.

Fusional stimuli located in different parts of the retinas and in-

ducing fusional movements in the opposite directions or different amounts of fusional movements in the same direction produce a diminution of the amplitudes of fusion. The extent of the diminution principally depends upon the location of the conflicting peripheral stimuli. In general, the less the separation of the stimuli and the closer they are to the fovea, the greater will be the diminution.

The effect of a relative magnification of one fusion stimulus on the amplitudes of vertical divergence was demonstrated for three different types of fusional stimuli, namely, foveal, peripheral, and a combination of foveal and peripheral stimuli. It was found that the unequal magnification always produces a diminution of the amplitude of vertical fusion. However, the extent of the diminution varies with the type of fusional stimuli and is smallest for single foveal stimuli. For differences in image size of less than 10 per cent for all the different types of targets employed, the relative variation of the amplitudes of fusion was not greater than 15 per cent.

ABSTRACTS

SOME FACTORS INFLUENCING FUTURE DEMANDS FOR OPTICAL CORRECTION. J. R. Warman. The Optician. (London). 118. pp 3-6. July 29, 1949.

The author believes the demand for refractive care in England will remain high. The only factors which will affect it are ignorance, indifference and laziness on the part of patients, as well as seasonal demand. He feels that, as the present compulsory health insurance program becomes better understood in England, these factors will be less in evidence.

He objects, however, to the current government proposal to abolish the Supplementary Ophthalmic Service (private practice) and transfer all National Health ophthalmic patients to the Hospital Eye Service. He feels this will, if carried out, do an enormous amount of psychological damage as many patients who are free from ocular pathology would worry if forced to attend an out patient clinic at a hospital for an eye examination.

C. C. K.

THE WEEK'S WORK. A. E. Turville. The Optician. (London). 117. pp 395-397. May 6, 1949.

The author describes his activities as an optometrist practicing in a city of 100,000. Before the current English compulsory health insurance program went into effect about 80 per cent of his work was re-refracting patients seen previously. Since the scheme, the number of cases refracted has increased and now about 50 per cent are persons never examined by him before. Three to six per cent of all his patients are referred to medical men for general or ocular pathology while about five per cent require no refractive care. The author says, "We must work longer hours, have fewer gaps, and economize in time in every way possible. We have no time to think or plan or discuss anything except how to avoid wasting time in clerical work! Research work has practically ceased . . . " Ninety-five per cent of his patients now come to him under the compulsory health program and only five per cent as independent patients. Materials are hard to get, yet the writer seems hopeful for the future of optometry in England.

V. H.

THE USE OF OCCLUSION IN THE TREATMENT OF AMBLYOPIA—FIVE CASE REPORTS*

Marian K. Eakin and Robert S. Eakin†
Los Angeles, California

The authors present the reports of five amblyopic patients, all boys ranging in age from seven to 11. We have chosen these cases as best representing some of the interesting similarities and dissimilarities of amblyopia and its treatment.

Case 1. J. H., age 7½, came to us on March 22, 1947, as a result of a note sent his mother by the school nurse. There had been no previous refraction. His only complaints were bloodshot eyes and headaches after movies.

His refraction disclosed. (1) Unaided visual acuity: O. D. 17/800, O. S. 20/20^{-1}. (2) Subjective: O. D. + 6.25 D. sph. ⊂ + 0.75 D. cyl. axis 180. O. S. + 0.50 D. sph. (3) Corrected visual acuity: O. D. 20/100^{+1}, O. S. 20/22. (4) The fundi were normal and there were no indications of any injuries.

Lenses for constant wear and occlusion of the left eye for all activities except school were prescribed. In May, 1947, his uncorrected visual acuity of the right eye was 20/267, corrected 20/29^{-2}. Constant occlusion with a Chavasse occluder was then prescribed for one month; his uncorrected visual acuity of the right eye in one month was 20/133^{+1}; corrected, 20/22^{-2}. By July, 1947, the uncorrected visual acuity was 20/40; corrected 20/20^{-2}. The Chavasse occluder was replaced by a plano lens and fusion training was initiated. He was able to fuse a Javal F and I, on the rotoscope if the light was dimmed enough for the left eye. The patient was given a hand stereoscope with Guibor cards for home training; he was given three sessions, each one month apart, using alternately the troposcope and the rotoscope. By October, 1947, the uncorrected visual acuity of the right eye was 20/25^{+2} and the corrected was 20/20^{-1}. He was able to fuse all of the Wells F series and most of the difficult fusion targets on the rotoscope. The patient had been wearing his correction constantly all during the training; not without some persuasion, however. By assuring him that he could never be a sailor like his father unless he had good eyes, we were able to keep the correction in place. As is so often the

*Submitted on June 30, 1949, for publication in the September, 1949, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrists.

case with the patient who has one emmetropic eye, he could not see that the lenses made any particular improvement in his binocular vision. The patient was dismissed for six months.

In May, 1948, we refracted him again. The findings were, (1) Unaided visual acuity: O. D. $20/33^{-3}$. O. S. $20/18^{-1}$. (2) Subjective: O. D. + 5.00 D. sph. $\bar{}$ + 0.75 D. cyl. axis 180. O. S. plano. (3) Corrected visual acuity: O. D. $20/20^{-}$. O. S. $20/18^{-1}$. (4) Distance phoria: 2 esophoria. (5) Fusional supplementary convergence: 2 exophoria. (6) Convergence amplitude: 2 inches. (7) Cover test: Negative.

The mother reports that her son has been wearing the correction constantly as he needs "good vision to be a major league ball player."

Case 2. M. P.: age 9, came to our office January 21, 1948, as a result of a note sent his mother by the school nurse. Both the patient and his mother were quite vociferous about the excellence of patient's vision. Even during the refraction his mother was unable to believe the child's inability to read the Snellen chart. For several years the patient had been suffering from headaches and bloodshot eyes after movies and had also been complaining about bright lights. There had been no previous refraction. An examination disclosed, (1) Unaided visual acuity: O. D. $20/100^{-1}$. O. S. $20/22^{-2}$. (2) Static and subjective: Plano in both eyes. (3) Ophthalmometry: 1.00 D with-the-rule for both eyes. (4) Distance phoria varied from ortho to 2 esophoria. (5) The patient had simultaneous vision on the troposcope.

Occlusion of the left eye for everything except school was prescribed despite the protests of the patient. In one week the unaided visual acuity of the right eye was $20/40^{-2}$. Simultaneous vision was elicited on the rotoscope with the pumpkin and unequal illumination. On February 19, 1948, the unaided visual acuity of the right eye was up to $20/33^{-1}$. We used target No. 27 on the rotoscope (a reduced Snellen) in front of the right eye only. By February 25th the unaided visual acuity of the right eye was 20/22. Fusion training on the Tel-Eye-Trainer with Pine fusion cards was started. We used constant illumination for the left eye and intermittent flashing for the right eye. Also some tracing on the cheiroscope was done. On May 4th his unaided visual acuity in the right eye was $20/20^{-2}$. Pine fusion targets on the Tel-Eye-Trainer were normal with equal illumination for each eye. We recommended the practice of projection with the right eye only at home. This was done by having someone else hold a pen or pencil in various positions and the patient would attempt to touch the end of the pen with his forefinger quickly and accurately. The visual

acuity was the same on May 18th and the patient passed the Javal F and L on the rotoscope perfectly. We dismissed the patient for three months; he was unable to return for a post-training check as the family moved out of the state.

Case 3. M. H., age 10, came to us for visual care on April 1, 1948, as a result of a note from the school nurse saying, "one eye is weak." The patient had been having bloodshot eyes every afternoon but no discomfort. He was a slow reader although not unusually so. There had been no previous refraction.

His findings were. (1) Unaided visual acuity: O. D. $20/17^{-2}$. O. S. $20/53^{-}$. (2) Subjective: O. D. plano. O. S. —1.00 D. sph. $\bar{}$ + 3.50 D. cyl. axis 90. (3) Corrected visual acuity: O. D. $20/17^{-2}$. O. S. 20/50. (4) Ophthalmometry: O. D. 90/44.50 D. and 180/44.25 D. O. S. 90/46.50 D. and 180/43.00 D. (5) Distance phoria: 4 esophoria. (6) There was no evidence of pathology.

We prescribed a full correction and occlusion of the right eye as much as possible. At the time of the progress report in June, 1948, the corrected visual acuity of the left eye was 20/33. The patient had worn the correction constantly but had simply refused to use the occluder.

The writers refracted this boy again in September, 1948, as he had lost his glasses. The findings were. (1) Subjective: O. D. + 0.25 D. cyl. axis 90. O. S. —0.75 D. sph. $\bar{}$ + 3.00 D. cyl. axis $82\frac{1}{2}$. (2) Corrected visual acuity: O. D. 20/17. O. S. $20/25^{-2}$. (3) Phoria: 3 esophoria. (4) Fusional supplementary convergence: 3 esophoria.

The patient frankly admitted he was interested only in his correction and not in any type of occlusion. He was quite comfortable with the glasses and could see no advantage to better visual acuity or improved binocular coordination.

Case 4. R. H., age 7, came to our office September 16, 1948, as a result of parents reading an article containing a description and a picture of the troposcope. Mrs. H. phoned our office to inquire if we possessed a troposcope. This seemed an unusual question. Further conversation elicited a history of a note from a school nurse and a diagnosis from another practitioner of "hopeless amblyopia" for which nothing could be done. The mother had been unwilling to accept this diagnosis and felt that she would try anything before accepting defeat. On her own initiative, she had devised a system of flash cards which she had her son attempt to read with the amblyopic eye.

His findings were. (1) Unaided visual acuity: O. D. 20/200. O. S. $20/20^{-1}$. (2) Static: O. D. + 6.25 D. sph. O. S. + 0.75 D. sph.

(3) Subjective: O. D. + 4.00 D. sph. O. S. Plano. (4) Convergence amplitude: 6 to 8 inches. (5) No evidence of pathology. (6) The angle of squint as measured on the troposcope: zero.

We prescribed the subjective finding for constant wear with occlusion of the left eye for everything except school. We also recommended continuation of the flash card system at home. Corrected visual acuity of the right eye at the time the correction was delivered was 20/114. In one week, the visual acuity was $20/100^{-1}$: the next week, it was 20/80: the next week, $20/73^{-1}$. For office training, we used the tachistoscope for monocular stimulation: the rotoscope and troposcope for basic fusion training: and the cheiroscope for hand-eye coordination. In November we gave him a hand stereoscope with some Guibor cards for home training. By November 18th, the corrected visual acuity of the right eye was $20/50^{-3}$, and the fusional ability was beginning to improve. By January 20, 1949, the visual acuity was $20/40^{-3}$ and it stayed there for the next six weeks. We had rechecked the subjective several times during this period and could find no better lens correction than the original +4.00 D. sph. In March the visual acuity had improved to $20/29^{-2}$. We were still using binocular training in the office and occlusion plus flash cards and hand stereoscope at home. In May for the first time, the patient was able to read two letters on the 20/25 line, with the B & L Clason acuity meter. For one month we did not see the patient at all as he had contracted chicken pox. On June 16th, we checked his visual acuity and it was exactly the same as in May.

Case 5. W. S., age 9, came to our office on February 26, 1949, as a result of a note sent the mother by the school doctor this semester and also a year ago. The first note had been ignored. Both notes said the left eye was bad. A year previously his family physician had recommended "exercising" the left eye by occlusion of the right, but he had not mentioned a correction or refraction. The patient himself had no complaint.

His findings were, (1) Unaided visual acuity: O. D. $20/20^{-1}$. O. S. 20/73. (2) Subjective: O. D. plano. O. S. + 2.00 D. sph. $\bar{}$ + 1.00 D. cyl. axis 90. (3) Corrected visual acuity: O. S. $20/40^{-2}$. (4) Distance phoria: two esophoria. (5) Fusional supplementary convergence: 6 esophoria. (6) Abduction: 2/0. (7) Negative reserve convergence: x/16/12. (8) Cover test: showed esophoria. (9) red glass: diplopia which could not be eliminated. (10) The fundi were normal.

The subjective findings were prescribed with occlusion of the right eye, for constant wear. In one month, at the time of the progress report, the corrected visual acuity of the left eye was $20/20^{-1}$. However, it

was necessary to use 6 Δ base-out prism to obtain single vision. We had arrived at this amount of prism through the use of the Turville infinity balance test. We supplied the patient a fitover with 3 Δ base-out prism in each eye to be worn for two weeks. When the patient returned, he reported complete comfort with the prisms and no diplopia at any time. The Turville test again showed 6 Δ base-out necessary, so we prescribed this amount in his permanent lenses. On the troposcope the patient showed an objective and subjective angle of squint of 12° base-out *through* his prism correction. He also showed 12° of abductive ability using the simplest troposcope target. In another month, he will return for a progress report. At that time, we shall consider the need for orthoptics.

SUMMARY

Several methods of occlusion are employed by the writers. For constant occlusion: the Chavasse occluder, several layers of colorless nailpolish applied crisscross on the lens, soaping the lens (ineffective with some children), and various types of plastic occluders which are attached to the lenses by suction cups. For intermittent occlusion: zylo patches over the lenses, soaping, medical eye shields (held by an elastic head band) for patients with no correction, and a cotton bandage applied with adhesive tape for children who pull off removable eye shields.

CONCLUSION

The authors have presented five case histories where occlusion was prescribed to improve visual acuity in amblyopic cases. The patients were all boys ranging in age from seven to 11. Four of the children wore some type of occluder as prescribed, and their corrected visual acuity improved. One boy refused to wear an occluder, being interested only in a correction. Corrections were prescribed in four cases, none in the fifth. Visual training was prescribed in three cases and may be prescribed in the fourth.

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ABSTRACTS

REPORT ON CASE FITTED WITH PLASTIC CORNEAL CONTACT LENSES. J. M. Cowan. The Dioptric News. (London), 4.9.151-152. 1949.

The author took "before" and "after" ophthalmometer readings on a two diopter myope who was fitted with corneal contact lenses. Before wearing the corneal contact lens the radius of cornea was 8.04 mm. After using the corneal contact lens for six hours the radius was 8.23 mm. Upon removal of the lens the patient's uncorrected visual acuity had improved. The eyes returned to their normal refractive state within 12 hours.

C. C. K.

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ESSENTIAL RESEARCH USUALLY UNDRAMATIC

In recent months, the subject of visual research has been widely discussed in optometric journals. This is due to the establishment of the Optometric Foundation and its current worthy campaign for funds. Though much that has been written is superficial, the interest which has been aroused in research is good, and should be directed and encouraged. Refractive work is in need of much factual data which can be assembled only through research studies made under the supervision of competent men.

The real science and art of ocular refraction is now well into its second century. One factor which has retarded progress has been that the work itself is largely clinical. It has been in the hands of optometrists and ophthalmologists who, while trained clinically, were not sufficiently grounded in the basic sciences which surround refractive work

to enable them to explore the subject and properly substantiate or refute the theories which developed. These theories then, were in part accepted in lieu of better evidence.

A second handicap has been the desire on the part of some to insist on research work only to the end that a pet idea or theory be upheld. Obviously, research work cannot function with merit under such circumstances.

To be successful, the research worker must be well trained in his specialty. He must have a flair for projecting into the future his systematic questions and thinking. He must approach his problem with an open mind and evaluate new data as they develop and not attempt to reshape his findings to conform with patterns, facts or theories already known, or believed. In addition to these qualities, he must have access to source material and must be thoroughly familiar with all of the work already done elsewhere by others in the specialty. He must have funds with which to work. He will require subjects, equipment, and a base of operations. And he must have time to do his work and the study that accompanies it.

It should be evident that this sort of work will not be spectacular. After months and sometimes years of work the first result will be a published manuscript in which the author reviews the literature, presents the problem, his attack upon it, his findings, comments and conclusions. The article will probably have a few illustrations and some tables. It will be conservatively written. It will make no extravagant claims. Frequently its initial connection with clinical refraction is obscure. But fundamentally, it will help tie together some of the loose ends of our work.

For example, the recent independent studies conducted by Allen[1] at the School of Optometry, Ohio State University, and by Marg and Morgan, Jr.,[2] at the School of Optometry, University of California, wherein these research workers made important photographic findings of accommodation and convergence changes in the living eye. These data, now being assembled, should be of assistance in solving several moot questions which have troubled us for years. Or, again, the far reaching project of Stenstrom as translated by Woolf.[3] All these re-

[1]Allen, Merrill J., An Objective High Speed Photographic Technique for Simultaneously Recording Changes in Accommodation and Convergence. Am. J. Optom. & Arch. Am. Acad. Optom. 26.7.279-289. 1949.

[2]Marg, Elwin and Morgan, Meredith W. Jr. The Pupillary Near Reflex. The Relation of Pupillary Diameter to Accommodation and the Various Components of Convergence. Am. J. Optom. & Arch. Am. Acad. Optom. 26.5.183-198. 1949.

[3]Stenstrom, S. Investigation of the Variation and the Correlation of the Optical Elements of Human Eyes. Translated by Daniel Woolf. Am. J. Optom. & Arch. Am. Acad. Optom. 25. May-October issues. 1948.

search studies have lasting merit. At times it appears that this work passes almost unnoticed. We regret to report that in the case of the Stenstrom translation, so little interest has been shown by optometrists in his findings on the anterior-posterior diameter of the eye and its relation to ametropia, that the Academy has held up publication of the material in monograph form. The Academy, after sending out two test letters to selected groups, is unable to determine at the moment, the quantity of Stenstrom monographs which might in the future be absorbed by the profession.

During the past 20 years the Academy has, through financial grants-in-aid, assisted a number of these studies. Each in turn has helped to clarify one or more points relating to refractive work. During this same period the American Optical Company, Bausch & Lomb Optical Company, the Univis Lens Company and others have also supplied grants-in-aid to make projects possible. Educational centers have secured additional funds to help these projects or to entirely finance other studies. While some progress has been made, much additional work of this type must be done. The Optometric Foundation is a welcome addition to the group who in this way are making lasting contributions to refractive science.

The directors of the Optometric Foundation realize that research is slow and usually undramatic. Some writers, however, fail to have this viewpoint, judging by recent articles. The Foundation can play an important part in optometric development if it assists in giving to the right man the time, place, equipment, supplies and money. But the Foundation will have to resist the pressures which will attempt to have it substantiate pseudo ideas through research.

CAREL C. KOCH.

ABSTRACTS

THE REGULATION OF CONTACT LENS PRACTICE. R. A. Tyler Jones. The Dioptric News. (London). 4.13.215-217. 1949.

The author suggests that all British optometrists who practice contact lens fitting be given special qualifying examinations before being recognized as specialists. Mention is made of the Contact Lens Section of the American Academy of Optometry and the qualifying procedure established by that organization.

V. H.

THE USE OF THE STEREOSCOPE IN THE TRAINING OF STUDENTS. P. H. Robb. The Dioptric News. (London). 4.15.247-250. 1949.

The author reviews the non-orthoptic uses of the stereoscope for educational purposes. The stereoscopic views on cinekodachrome filmstrips as well as the black and white views are ideal for teaching anatomy and other subjects where a three dimension view is essential.

C. C. K.

SPECIAL REPORT

AMERICAN OPTOMETRIC FOUNDATION ANNOUNCEMENT OF FELLOWSHIPS*

William C. Ezell†
Spartanburg, South Carolina

The directors of the Foundation are happy to announce the offer of three $1,500.00 fellowships for the academic year 1949-50. This is the first move of the Foundation in support of education and research in optometry. These fellowships are offered primarily to encourage prospective teachers in schools and colleges of optometry to continue with programs of graduate education leading to the Ph.D. degree, or to aid graduates from schools and colleges of optometry to prepare themselves for teaching and research positions in optometry by pursuing a graduate program leading to the Ph.D. degree.

The fellowships are open to any graduate optometrist. A candidate, if selected for a fellowship, may pursue his graduate program at any institution granting the Ph.D. degree. The fellowship is for a period of nine months. During these nine months he must be enrolled as a resident in a graduate school. He will be expected to spend not less than two-thirds of his time in the pursuit of his graduate program, and at least one-third of the total time must be devoted to research on the subject proposed as a basis for securing the fellowship. The program selected for investigation may be changed at any time if it meets with the consent of the Foundation. During the time of the enrollment in a graduate school under the fellowship, the fellow may engage in a part-time teaching position or graduate assistantship to the extent of one-third of his time.

Any publications arising out of the work sponsored by the Foundation must give due credit to the Foundation, unless the Foundation elects to have mention of its sponsorship omitted. Consequently, all publications must be submitted to the Foundation for approval of the mention of sponsorship.

Fellowships may be renewed once each year if funds are available and if satisfactory progress is shown. The renewal of a fellowship for

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†Optometrist, Fellow, American Academy of Optometry, President, American Optometric Foundation.

a second year does not presuppose the continuation of work on the same problem.

A report of progress will be required at the end of each year; and, in case the fellowship is not renewed for a subsequent year, the report at the end of the year can be considered to be a final report.

Preference will be given to applicants who show the most promise for a useful career of teaching and research in optometry, but consideration will also be given to the merits of the project on which the candidate proposes to work.

The candidate must begin work on the fellowship not later than October 1, 1950, and must complete the work prior to October 1, 1951.

The deadline for filing applications will be September 1. If fellowships are still available after applications filed by September 1 have been considered, applications filed after that date will be evaluated as soon as possible, and one of the available fellowships will be awarded if the Foundation regards the candidate and his project worthy of support. Funds for fellowships not granted by January 1, 1950, will be reallocated in subsequent years. The Foundation reserves the right to refuse all applications for fellowships if, in the opinion of the directors, the requirements are not met.

The awarding of a fellowship is in each case provisional and does not become final until after satisfactory completion of registration in the graduate school specified in the application or an alternate approved by the Foundation.

All who are interested in receiving one of these fellowships should immediately write for an application blank and further details to the president of the Foundation, Dr. William C. Ezell, 205 Andrews Building, Spartanburg, South Carolina.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

ACADEMY JOINS A. A. A. S.

The American Academy of Optometry has been granted the status of an associated society of the American Association for the Advancement of Science, a century-old organization dedicated to the promotion of human welfare through science. More than 40,000 scientists from

every field of scientific endeavor belong to the A. A. A. S., which has 206 affiliated and associated societies. In addition to conducting special meetings for those interested in science, the Association publishes two journals, *Science* and the *Science Monthly*.

COMMISSION STUDIES EFFECT OF RADIANT ENERGY ON LENS

The Atomic Energy Commission, according to its latest report to Congress, is making every effort to avoid one of mankind's commonest mistakes—failing to utilize a new discovery for the benefit of the human race. In its semi-annual report, issued to the press last month, the Commission points out that, for example, sulphuric ether, x-rays and gasoline were not made fully useful to man until many years after their original discovery. The Commission hopes to avoid a similar situation with radiant energy. Every possible research is being conducted to explore the use of radiant energy in biology and medicine and other scientific fields. In addition to exploring peacetime uses, an ophthalmological survey of survivors of the Hiroshima and Nagasaki bombings is currently being conducted. Particular attention is being paid to the incidence and severity of radiation cataracts. The survey will supplement work being conducted in the United States on persons who have developed radiation cataracts while working in the vicinity of radiation producing machines and substances.

COMMERCIAL PRACTICE HIT IN MINNESOTA

Following a series of discussion meetings, the Minneapolis District Optometric Association gave its commercially-practicing members an ultimatum: practice professionally or withdraw from the district association. Under the leadership of its president, Dr. A. E. Tillisch, the association passed the following resolution:

"After consideration by the officers and executive committee of the Minneapolis District Optometric Association, it is recommended that membership in this local optometric society be limited to optometrists and their assistants who are in exclusive optometric practice.

"It is further recommended that the Minneapolis District Optometric Society go on record urging the Minnesota State Optometric Association to take similar action regarding membership in the State association.

"It is further recommended that the Minnesota State Board of Examiners in Optometry study the problem of corporate practice of optometry and optometric practice in connection with jewelry and other mercantile stores to eliminate this evil, through legal measures if necessary."

Prior to passage of the resolution on August 3, Dr. Tillisch called special meetings to give members a chance to thoroughly discuss the matter. Sixteen optometrists were affected by the resolution. Approximately 100 optometrists practice in Minneapolis.

Shortly after the action by the Minneapolis District Association, the board of directors of the Minnesota State Optometric Association passed a similar resolution barring from its membership optometrists engaged in commercial type practice.

The Minnesota group is the second state association to pass such a resolution, New Jersey being the first on record to limit membership to professionally practicing optometrists.

COLOR FILM ON LIGHTING AVAILABLE

A Kodachrome sound-slide film dramatizing the need for better lighting in schools is now available from the Better Light Better Sight Bureau. "Educating in a Truer Light" runs 22 minutes; emphasizes the importance of securing support from parents when planning school modernization programs. Full-color illustrations of school rooms, "before and after" are included in the film which is being used by electric utilities, electrical leagues and civic groups interested in planned school lighting. The rental fee for the film, with sound track, is $50.00. A 6-page booklet which condenses the story in the film is also available at $5.00 for 100 copies. The address of the Better Light Better Sight Bureau is 420 Lexington Avenue, New York 17, New York.

A. O. A. ISSUES MOTORISTS' VISION MANUAL

Cooperation between the American Optometric Association and the American Association of Motor Vehicle Administrators has resulted in a new manual on motorists' vision which will help standardize testing procedures in the United States. The booklet, released in August, outlines the procedure for giving visual acuity tests to motorists and emphasizes the part vision plays in safe driving. Material in the manual is based on research work at The Ohio State University through an A. O. A. grant, and studies at Iowa State College. Work on the booklet, "Manual on Drivers' Vision Tests," was started by Dr. E. H. Silver of Washington, D. C., when he was chairman of the A. O. A. Motorists' Vision committee, and completed under the direction of Dr. Kenneth H. MacPherson, Stockton, California, present chairman, and Dr. E. F. Richardson, Hollywood, California, trustee consultant. The American Association of Motor Vehicle Administrators helped plan and interpret the work in terms of driver license administration, and is aiding the A. O. A. in distribution of the pamphlet.

The purpose of the manual is to guide state driver license examiners in screening license applicants, and tests are recommended which can be applied by laymen to discover cases which need further attention, according to Dr. Soles, A. O. A. Public Information director.

NEWS BRIEFS

Bay State Optical Company and the Soft-Lite Lens Company have recently announced appointment of seven-man advisory boards to help management formulate plans and policies for the coming year. The men were chosen from leaders of various sections of the optical industry. . . . Dr. Carl Shepard, Chicago, will end 26 years of optometric teaching when he retires October 1. He has been head of the Northern Illinois College of Optometry research department for 13 years, as well as an instructor. Dr. Shepard will continue as technical editor of the *Optometric Weekly* and practice in Chicago. . . . The American Optical Company has received its fifth safety award in four years—the Distinguished Service to Safety Award of the National Safety Council. Governor Paul A. Dever of Massachusetts made the principal speech at award ceremonies held in Southbridge on August 3. . . . The A. O. A. launched its most ambitious school vision program to date in August. An unprecedented number of news releases, radio scripts, pamphlets were released for use by state optometric associations in their "Send the Whole Child to School" projects. . . . The American Ophthalmological Society voted to revoke memberships of any member found guilty of taking rebates. The action was taken at its 1949 annual meeting. . . . Officers who will serve the recently organized Society for Strabismus Research during the coming year are Dr. Neal J. Bailey, Escanaba, Michigan, president; Dr. Marilyn Brenne, Manitowoc, Wisconsin, recording secretary; Dr. Dorothea McCoy, Wichita, Kansas, corresponding secretary, and Dr. Leo Madigan, Boston, Massachusetts, treasurer. Committee chairmen for the group are: Membership, Dr. Howard Bartlett, Boston, Massachusetts; research, Dr. I. W. Kinsey, Alliance, Ohio; finance, Dr. Dean Ambrose, Charleston, Illinois; publication, Dr. Milton Covell, Pasadena, Texas; education, Dr. Fred Jennings, Tiffin, Ohio; organization, Dr. William Sullins, Athens, Tennessee. . . . Univis Lens Company wound up its series of classes for distributors at Columbus, Ohio, on August 6. Purpose of the school was to give representatives an insight into the problems of the refractionist. A special textbook was prepared for the course by George Knox, Ph.D., and Vincent Ellerbrock, Ph.D., who served as instructors.

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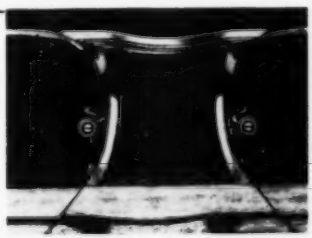

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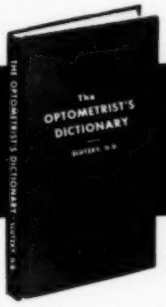

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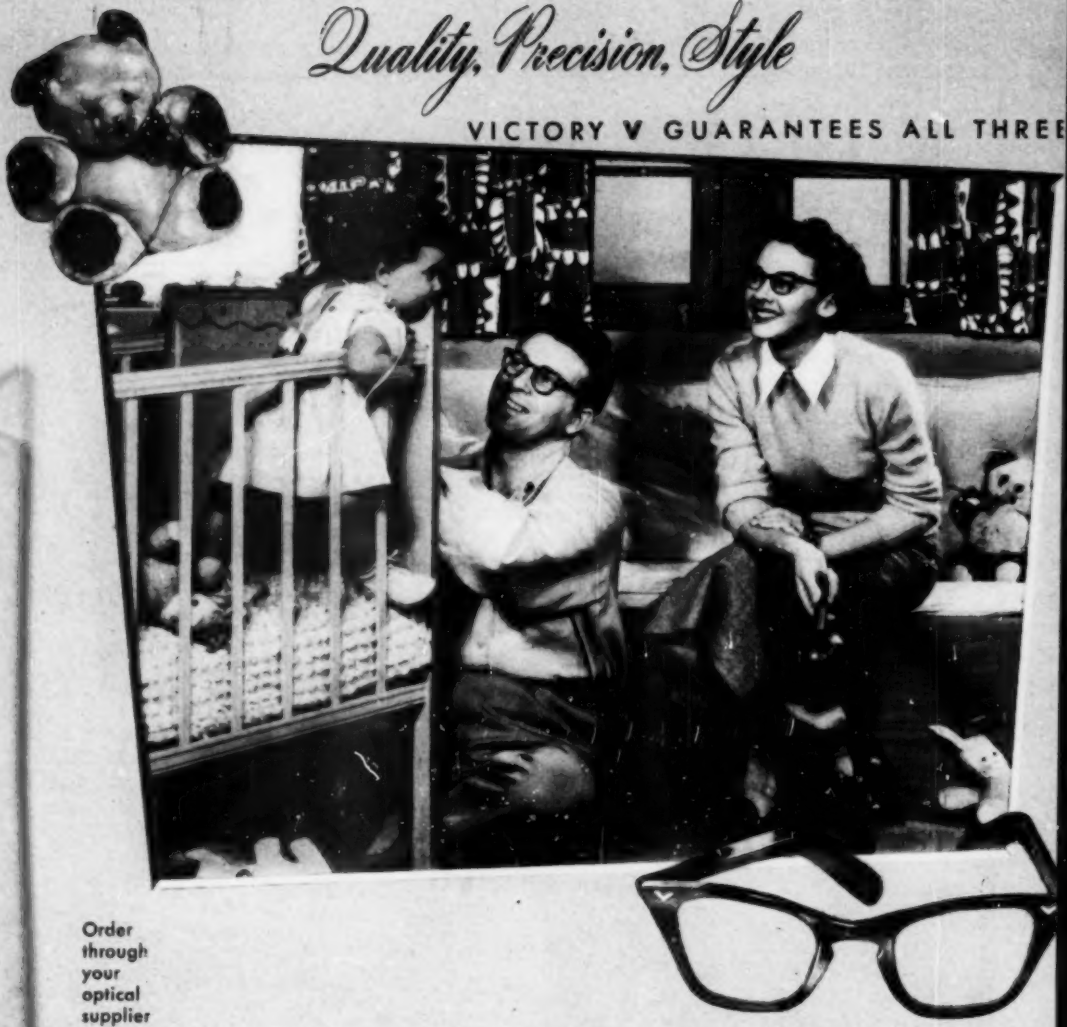

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